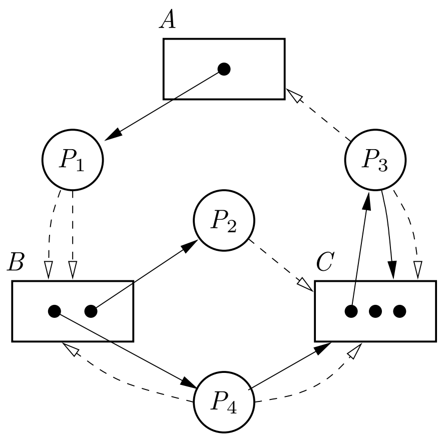
# Solutions for CP Exercise Class 6

## 1. Solution for CP Exam December 1998, Problem 4

### Question 4.1




### Question 4.2

(a) Finishing processes satifying their maximum demands:

| *Available* A | B | C | *Can be finished* |
|---|---|---|---|
| 0 | 0 | 2 | $P_2$ |
| 0 | 1 | 2 | $P_4$ |
| 0 | 2 | 2 | $P_1$ |
| 1 | 2 | 2 | $P_3$ |
| 1 | 2 | 3 | |

Since a sequence exists in which all the processes can have their maximal resource demands satisfied, the situation is *safe*.

(b) Even though $P_4$ is granted a $C$-instance, the above sequence is still possible and the situation is still safe. Thus, $P_4$ may be granted a $C$-instance according the bankman's algorithm.

**2.**

**process** *Merge* =
  **var** $x$ : *integer*;
  **do** $A\,?\,x \rightarrow C\,!\,x$
  $[]$ $B\,?\,x \rightarrow C\,!\,x$
  **od**

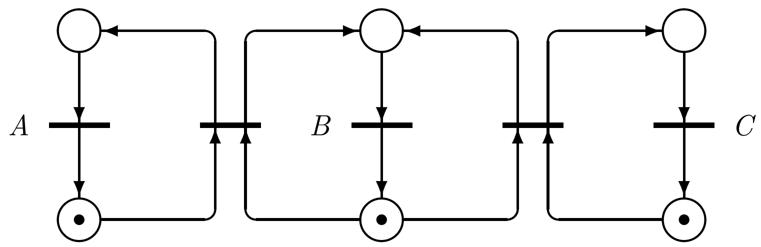
**3.**

**process** *Sum* =
  **var** $x, y$ : *integer*;
  **repeat**
    **if** $A\,?\,x \rightarrow B\,?\,y$
    $[]$ $B\,?\,y \rightarrow A\,?\,x$
    **fi**;
    $C\,!\,x + y$
  **forever**

## 4. Solution for Exam June 1994, Problem 3

### Question 3.1

Before each round, $P_2$ must synchronize with *either* $P_1$ or $P_3$. A Petri-net expressing this is:




### Question 3.2

[A synchronization can be implemented by signalling forth and back using two semaphores. A choice between two synchronizations is then implemented by using a common semaphore for the signalling:]

**var** $S_{AC}, S_B$ : *semaphore* := 0;

| | | |
|---|---|---|
| **process** $P_A$ = | **process** $P_B$ = | **process** $P_C$ = |
| **repeat** | **repeat** | **repeat** |
| `P`($S_{AC}$); | `V`($S_{AC}$); | `P`($S_{AC}$); |
| `V`($S_B$); | `P`($S_B$); | `V`($S_B$); |
| $A$ | $B$ | $C$ |
| **forever**; | **forever**; | **forever**; |

[Alternatively, `P` and `V` may be exchanged in all three processes.]

**5.** In order to meet, all processes must synchronize pairwise by CSP-communications. Care must be taken to avoid deadlock.

| | | |
|---|---|---|
| **process** $P_1$ = | **process** $P_2$ = | **process** $P_3$ = |
| **repeat** | **repeat** | **repeat** |
| $P_2\,!\,()$; | $P_1\,?\,()$; | $P_2\,?\,()$; |
| $P_3\,?\,()$; | $P_3\,!\,()$; | $P_1\,!\,()$; |
| $\vdots$ | $\vdots$ | $\vdots$ |
| **forever** | **forever** | **forever** |

## 6. Solution for Andrews Ex. 7.7

```
type Id = 1..n;
type Time = integer;
type Op = GetClock(Id) | Delay(Id, integer) | Tick;

chan request : Op;
chan reply[Id] : Time;
chan go[Id] : ();

process User[i : Id] =
  ...
  send request(GetClock(i));                       — Get clock
  receive reply[i](clock);
  ...
  send request(Delay(i, period));                  — Delay
  receive go[i]();
  ...


process Timer =
  var op : Op;
      q : PrioQueue<(Time, ID)>;
      time : Time := 0;
  repeat
    receive request(op);
    case op :
      GetClock(id):  send reply[id](time);
      Delay(id, p):  insert(q, (time + p, id));
      Tick:          time := time + 1;
                     while nonempty(q) ∧ min(q).Time <= time do
                       { send go[min(q).Id](); deletemin(q) }
    end case
  forever
```

Here *PrioQueue*< $T$ > is a priority queue of elements of type $T$ with standard operations *insert*, *min*, and *deletemin*. Tuples are assumed to be ordered lexicographically starting with the first component (here the *Time* component).

## 7. Solution for Andrews Ex. 7.16

Here, the problem is solved using a single *probe* sent along a ring of processes. In the probe, one of the processes gives a proposal for the least common value. If a process can agree, it passes on the probe, otherwise it makes a new proposal. When a proposal has traversed the ring, a *commitment* message (Done) is sent around.

```
type Id = 1..n;
type Val = integer;
type Op = Probe(Id, Val) | Done

chan in[Id] : Op;

process P[i : Id] =
  var values : set of Val := ...;
      op : Op;
      lcv : Val;                                        — Least Common Value
  lcv := smallest v ∈ values;
  if i = 1 then send in[2](Probe(i, lcv));
  repeat
    receive in[i](op);
    case op :
      Probe(id : Id, val : Val): if id ≠ i then
                                   { lcv := smallest v ∈ values such that v ≥ val;
                                     if lcv > val then { id := i;  val := lcv};
                                     send in[i mod n + 1](Probe(id, val) }
                                 else
                                   { send in[(i mod n + 1](Done);
                                     receive in(op); }
      Done:                      send in[i mod n + 1](Done);
    end case
  until op = Done;
```

When all processes have left the **repeat**-loop, they all have the correct value of *lcv* (assuming it exists) and the channels are empty.

The problem can be solved in many other ways, e.g. by passing several probes simultaneously, or using centralized or symmetric communication schemes.